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Abundance of Epiphytic Dinoflagellates from Coastal Waters off Jeju Island, Korea During Autumn 2009

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Abstract – The occurrence of harmful epiphytic dinoflagellates is of concern to scientists, the aquaculture industry, and government due to their toxicity not only to marine organisms but also to humans. There have been no studies on the abundance of the epiphytic dinoflagellates in Korean waters. We explored the presence of epiphytic dinoflagellates in the coastal waters off Jeju Island, southwestern Korea. Furthermore, we measured the abundance of epiphytic dinoflagellates on the thalli of 24 different macroalgae, collected from five different locations in October 2009. Five epiphytic dinoflagellate genera *Amphidinium*, *Coolia*, *Gambierdiscus*, *Ostreopsis*, and *Prorocentrum* were found. These five genera were observed on the thalli of the macroalgae *Chordaria flagelliformis, Martensia* sp., *Padina arborescens,* and *Sargassum* sp., while none were observed exceptionally on *Codium fragile*. The abundance of *Ostreopsis* spp. was highest on *Derbesia* sp. (8,660 cells/g wet weight), while that of *Gambierdiscus* spp. was highest on *Martensia* sp. (4,870 cells/g-ww). The maximum abundances of *Amphidinium* spp., *Coolia* spp., and *Prorocentrum* spp. were 410, 710, and 300 cells/g-ww, respectively. The maximum abundance of *Coolia* spp., *Gambierdiscus* spp., and *Ostreopsis* spp. obtained in the present study was lower than for other locations reported in literature. The results of the present study suggest that the presence and abundance of epiphytic dinoflagellates may be related to the macroalgal species of the coastal waters of Jeju Island.

Key words – *Amphidinium*, *Gambierdiscus*, HAB, *Ostreopsis, Prorocentrum*, red tide

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1. Introduction

Species in the genera *Gambierdiscus*, *Ostreopsis*, *Coolia*, *Prorocentrum*, and *Amphidinium* are known to be epiphytic and/or benthic dinoflagellates (Taylor 1979, 1995, Hurbungs et al. 2001). Most of the epiphytic dinoflagellates is harmful to humans as well as to marine organisms, to which scientists, the aquaculture industry, and government are keenly attentive (Bagnis et al. 1980; Alcala et al. 1988; Mangialajo et al. 2008). The majority of these dinoflagellates are known to be present in tropical or subtropical regions (Steidinger and Tangen 1997), but some species also live in the warm waters of temperate regions (Hurbungs et al. 2001; Pistocchi et al. 2011). The occurrence of epiphytic and benthic dinoflagellates in temperate waters has been reported as evidence of increasing water temperature (Graneli et al. 2011; Rhodes 2011).

Recently, Jeong et al. (submitted) reported the presence of *Coolia* spp. in the coastal waters of Jeju Island, southwestern Korea. However, this paper did not report the presence of the other epiphytic dinoflagellates at Jeju Island. We provide the first account of the occurrence of *Gambierdiscus*, *Ostreopsis* and epiphytic *Prorocentrum* and *Amphidinium* spp. from the coastal waters of Jeju Island. Additionally, we report the abundance of these epiphytic dinoflagellates, and the diverse macroalgal species on which they were found. The results of the present study should provide a basis for better understanding the ecology of epiphytic dinoflagellates in Korean waters.

2. Materials and Methods

To measure the abundance of epiphytic dinoflagellates, macroalgal samples (24 different algal species) were collected by divers at 1-3 m depth off Hahnlim, Kosahn, Sahgye, Namwon, and Seongsan, Jeju Island, Korea (Fig. 1), on October 30 and November 1st, 2009. The water temperature and salinity were 21.0-23.6 °C and 29.2-31.6, respectively (Table 1). The samples were placed in plastic bags and then fixed with buffered 3% formaldehyde. Additional samples were placed in plastic bags, and then stored in ice-boxes, and then transported to the laboratory. The fixed macroalgal samples were vigorously shaken to detach dinoflagellates from the thalli of the algae and then screened through a 500 μm Nitex mesh. Filtrates were concentrated to 1/5-1/10 after settling down the cells for 48 h. After being well mixed, all or >300 cells in one 1-ml Sedgwick-Rafter counting chamber were counted under a light microscope. The wet weight of each macroalgal sample was measured using a balance (Model CUW620H, CAS, Korea). Cells (not preserved) were collected from the macroalgal samples and photographed using a digital camera (Zeiss AxioCam HRc5, Carl Zeiss Ltd. Göttingen, Germany).

3. Results and Discussion

Five epiphytic dinoflagellate genera *Amphidinium*, *Coolia*, *Gambierdiscus*, *Ostreopsis*, and *Prorocentrum* were found in the coastal waters of Jeju island, Korea on October 31

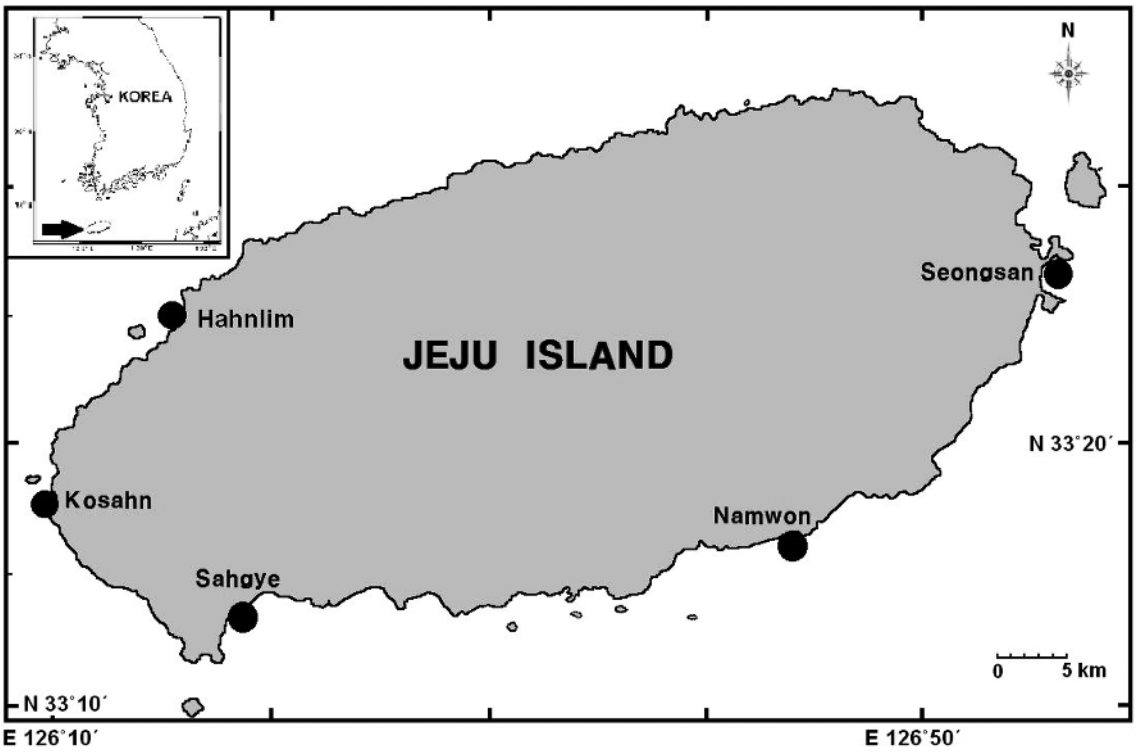

Fig. 1. The five sampling sites at Jeju Island, southwestern Korea

Table 1. Water temperature (T, °C) and salinity (S) in the locations where macroalgae were collected on October 31 and November 1, 2009

Location	Latitude	Longitude	Temperature	Salinity
Hahnlim	N 33°24′25.46″	E 126°14′30.02″	21.1	28.9
Kosahn	N 33°17′52.30″	E 126°09′42.22″	21.8	31.1
Sahgye	N 33°13′34.24″	E 126°18′25.63″	23.6	31.6
Namwon	N 33°16′28.99″	E 126°42′56.96″	22.1	29.2
Seongsan	N 33°27′23.65″	E 126°55′45.37″	21.0	32.5

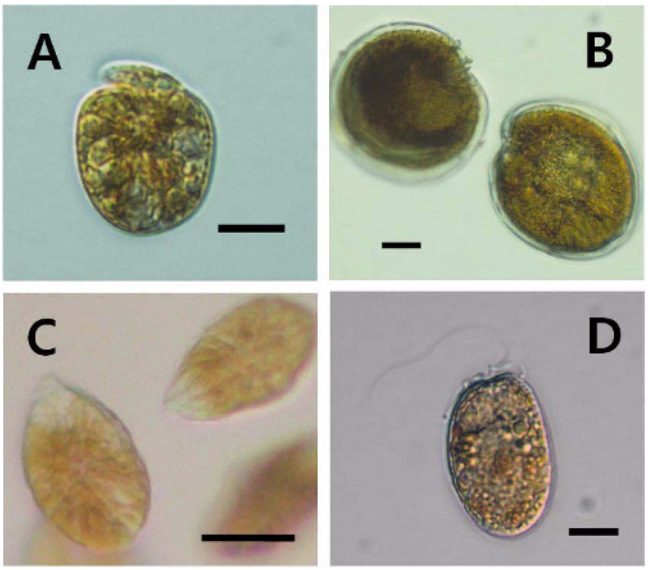

Fig. 2. Epiphytic dinoflagellates observed in this study. (A) *Amphidinium* sp. bar = 10 um. (B) *Gambierdiscus* sp. bar = 20 µm. (C) *Ostreopsis* sp. bar = 20 µm. (D) *Prorocentrum* sp. bar = 10 µm

and November 1, 2009 (Fig. 2). All were observed on the thalli of the macroalgae *Chordaria flagelliformis, Martensia* sp., *Padina arborescens,* and *Sargassum* sp.. Furthermore, *Coolia*, *Gambierdiscus*, *Ostreopsis*, and *Prorocentrum* were observed on the thalli of the macroalgae *Ulva pertusa*, *Ecklonia caba,* and *Chondrus ocellatus*. However, none of these genera were observed with *Codium fragile* (Table 2). *Amphidinium* spp. were observed with seven macroalgal species (*Cladophora wrightiana*, *Sargassum* sp., *Dictyopteris divaricata*, *C. flagelliformis*, *P. arborescens*, and *Martensia* sp.), *Coolia* with seven macroalgal species (*U. pertusa, E. caba, Sargassum* sp., *C. flagelliformis*, *P. arborescens*, *Martensia* sp., and *C. ocellatus*), while *Prorocentrum* spp. with eight macroalgal species (*U. pertusa*, *E. caba, Sargassum* sp., *D. divaricata*, *C. flagelliformis*, *P. arborescens*, *Martensia* sp., *Gelidium amansii*, *Corallina* sp.). *Gambierdiscus* spp., were observed with all macroalgal species except *C. fragile* and *Sargassum siliquastrum*, while *Ostreopsis* spp. were observed with all macroalgal species except *C. fragile*,

Table 2. The abundance (cells/g wet weight) of the epiphytic dinoflagellates *Amphidinium* spp., *Coolia* spp., *Gambierdiscus* spp., *Ostreopsis* spp., *Prorocentrum* spp. on diverse macroalgae collected from 5 stations along the coasts of Jeju Island, Korea on October 31-November 1, 2009

	Macroalgae\Epiphytes	*Amphidinium*	*Coolia*	*Gambierdiscus*	*Ostreopsis*	*Prorocentrum*
Chlorophyta	*Cladophora wrightiana*	0–15	0	39	758	0
	Ulva pertusa	0	0–237	500	342	29–53
	Cladophoropsis herpestica	0	0	173	231	0
	Derbesia sp.	0	0	1,595	8,660	0
	Codium fragile	0	0	0	0	0
Phaeophyta	*Dictyopteris prolifera*	0	0	60	164	0
	Ecklonia caba	0	0–33	17–53	5–69	8
	Dictyota okamurae	0	0	1,000	185	0
	Sargassum siliquastrum	0	0	–	121	0
	Sargassum sp.	0–10	0–121	343	434	30
	Dictyopteris divaricata	0–37	0	13–200	87–216	12
	Chordaria flagelliformis	0–121	0–339	1,770	364	97
	Zonaria diesingiana	0	0	111	44–94	0
	Padina arborescens	0–137	0–652	789	583	171
	Colpomenia sinuosa	0–68	0	136	545	0
	Dictyopteris undulata	0	0	62	–	0
Rhodophyta	*Plocamium cartilagineum*	0	0	255	255	0
	Pterocladiella capillacea	0	0	1,599	837	0
	Lithothamnion sp.	0	0	25	–	0
	Martensia sp.	0–406	0–710	4,871	3,349	304
	Gelidium amansii	0	0	229–426	78–688	233
	Corallina sp.	0	0	33–993	28–307	33
	Chondrus ocellatus	0	0–47	63	267	0
	Plocamium telfairiae	0	0	406–1477	50–966	0

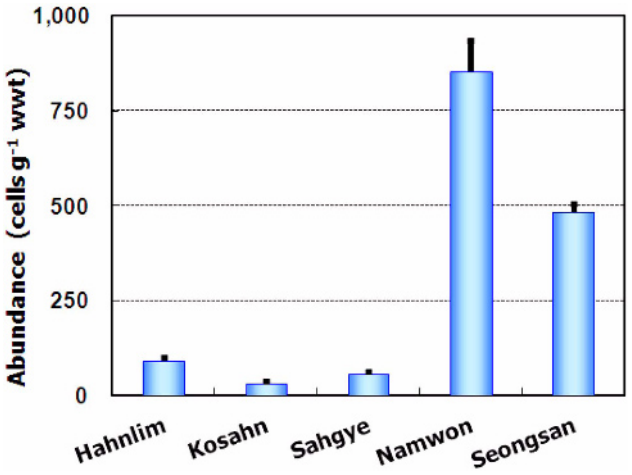

Fig. 3. Mean abundance of epiphytic dinoflagellates in each of the five stations. Error bar represents standard error of mean

Dictyopteris undulata, and *Lithothamnion* sp. (Table 2). The data suggest that the presence of these five epiphytic dinoflagellate genera is affected by the macroagal species in the study area.

The presence of the five epiphytic genera on the four macroalagal species, i.e. *C. flagelliformis, Martensia* sp., *P. arborescens,* and *Sargassum* sp., contrasts with their absence from a green alga, *C. fragile. Codium fragile*, however, was observed only at St. Kosahn where the coastline is more exposed than St. Namwon or Seongsan. Samples from St. Kosahn and Sahgye gave far lower abundance of epiphytic dinoflagellates than the other two embayment stations (Fig. 3). The unexpected absence of epiphytic dinoflagellates from *Codium fragile* and the far lower abundance on macroalgae from more exposed sites may be related with species interactions of the epiphytes with physical and biological environment. Shaking effect due to turbulent water at the open coast (physical-biological interaction) and/or diverse bi-species interaction among different macroalga-epiphyte combinations may limit or support their success (Bomber et al. 1989).

The evidence suggests that *Derbesia* sp. is the optimal macroalgae for *Ostreopsis* spp., while *Martensia* sp. may be the optimal macroalgae for the other dinoflagellate genera studied herein (Table 2). However, abundance of epiphytic dinoflagellate estimated by cells per unit weight of substrate macroalgal blade tends to become higher on such macroalgal species with higher surface to volume ratio as *Derbesia* sp. and *Martensia* sp..

The maximum abundance of *Gambierdiscus* spp. (~5×10^3 cells/g ww) obtained in the present study is lower than that of *G. toxicus* from the Gambier Islands, Pacific Ocean (500×10^3 cells/g ww; Yasumoto et al. (1980). The maximum abundance of *Ostreopsis* spp. (~9×10^3 cells/g ww) obtained in the present study is also quite lower than elsewhere (400-2,500$\times10^3$ cells/g ww; Table 3). This might imply that the environmental conditions in the study area is at sub-optimal level to the five epiphytic dinoflagellate genera, which are presumably "settling down and adapting themselves" to the increasing water temperature of Jeju coastal waters.

Table 3. Comparison of the maximum abundances (MA, $\times10^3$ cells/g wet weight) of the epiphytic dinoflagellates *Amphidinium* spp., *Coolia* spp., *Gambierdiscus* spp., *Ostreopsis* spp., *Prorocentrum* spp. obtained in the present study and those reported in literature

Genus	location	MA	Reference
Amphidinium spp.	Jeju Island, Korea	0.41	This study
Coolia spp.	Jeju Island, Korea	0.71	This study
C. monotis	Virgin Islands, Caribbean Sea	1,200	Calson & Tindall (1985)
Gambierdiscus spp.	Jeju Island, Korea	4.87	This study
G. toxicus	Gambier Islands, Pacific Ocean	500	Yasumoto et al.(1980)
Ostreopsis spp.	Jeju Island, Korea	8.66	This study
O. ovata	Genoa, Italy	2,541	Mangialajo et al. (2008)
O. siamensis	Auckland, New Zealand	1,406	Shears & Ross (2009)
Ostreopsis sp.	NW Mediterranean Sea	590	Vila et al. (2001)
Ostreopsis spp.	North Aegean Sea, Greece	405	Aligizaki & Nikolaidis (2006)
Prorocentrum spp.	Jeju Island, Korea	0.30	This study
P. mexicanum	Virgin Islands, Caribbean Sea	1,500	Calson & Tindall (1985)

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